UPDATE ON IGSM2 RELEASE

IGSM2 User's Group Meeting

April 18, 2003

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California Department of Water Resources

IGSM2: Description

- A comprehensive integrated hydrological model that simulates groundwater flow, surface flows, and surface-groundwater interaction
- A planning tool as it computes agricultural and urban water demands based on land use and crop types and allows user to specify water supply to meet the demand
- A ***successor*** to IGSM (version 5.0). IGSM2 has a new engine that uses mathematical and numerical techniques that are consistent with the current practices

Overview of Work Performed

- Analysis and documentation of IGSM 5.0 code *(15 months)*
- Modifications and improvements on theory and programming structure to create IGSM2 *(6 months)*
- 3 beta version releases to selected parties *(3 months)*
- IGSM2 v1.0 made available to public in December 2002 accompanied by a 3-day workshop
- IGSM2 v1.01 made available to public in January 2003
- Next version release with improvements/additions and workshop planned for the end of 2003

Principle Findings of IGSM Peer Review
(LaBolle, Ahmed and Fogg, 2002)

- **Improperly implemented head-dependent boundaries (GHBs, stream-aquifer interaction, lake-aquifer interaction, tile drains)**
- **Problems in simultaneously converging groundwater and surface water models**
- **Explicit formulation of head dependent transmissivity**
- **Problems associated with fixed monthly time step**
- **Lack of adequate documentation of the theory, computer code and verification problems**

Implementation of Head-Dependant B.C.

- General equation:

$$Q = C\left(h_B - h_g\right)$$

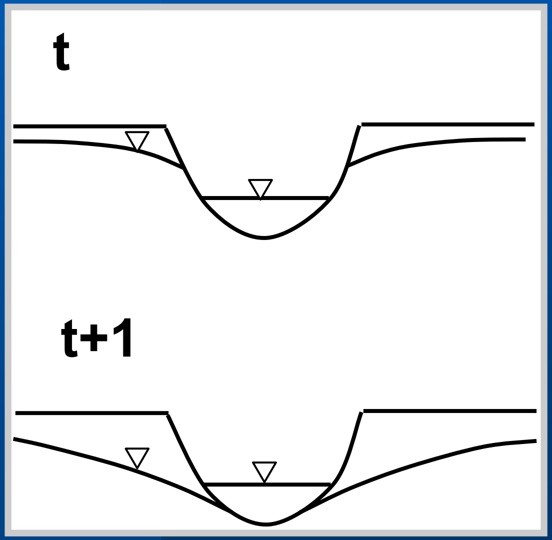
- Proper implementation of head dependant boundary conditions into the system of equations modifies coefficient matrix and r.h.s. vector:

$$\begin{pmatrix} A_{11} & \cdots & A_{1n} \\ \vdots & \ddots & \vdots \\ A_{n1} & \cdots & A_{nn} \end{pmatrix} \begin{Bmatrix} h_1^{t+1} \\ \vdots \\ h_n^{t+1} \end{Bmatrix} = \begin{Bmatrix} F_1^{t+1} \\ \vdots \\ F_n^{t+1} \end{Bmatrix}$$

Implementation of Head-Dependant B.C. *(continued)*

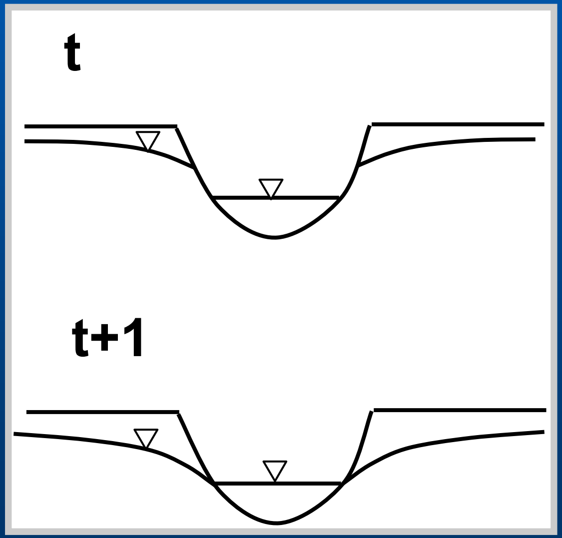
- **Explicit modeling (IGSM)**

$$Q = C\left(h_B^t - h_g^t\right)$$



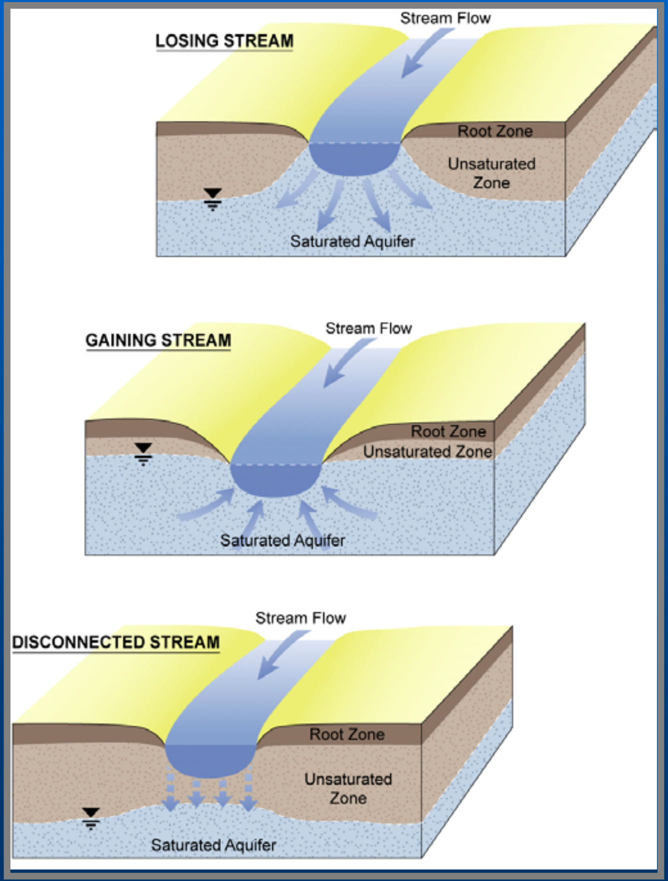
- **Implicit modeling (IGSM2)**

$$Q = C\left(h_B^{t+1} - h_g^{t+1}\right)$$



Stream Flow and Stream-Aquifer Interaction

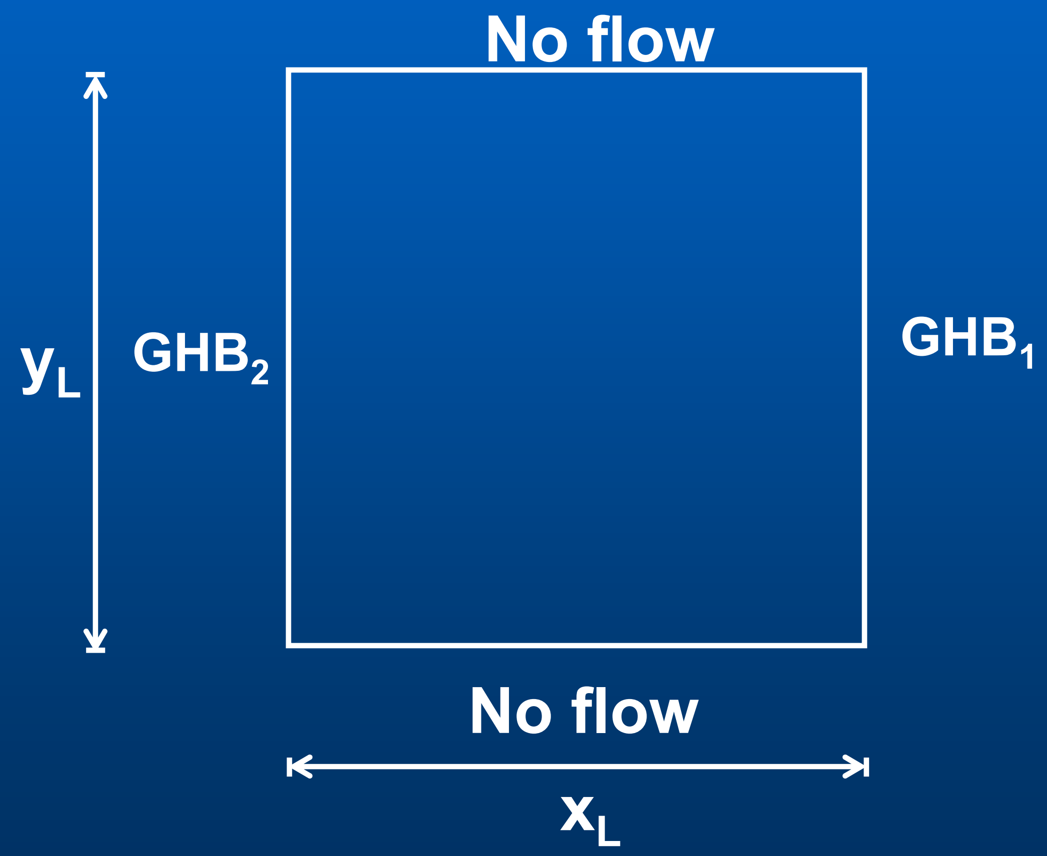
- Assumption of zero storage at a stream node in computing stream flows; i.e. $Q_{in} = Q_{out}$
- Fully coupled stream flow and groundwater equations in computing the stream-aquifer interaction
- Stream-aquifer interaction is computed implicitly with an iterative method



Comparison of Performance: IGSM2 and MODFLOW (from CWEMF review of IGSM)

Problem 1c

- $h_o = h_1 = 200$ ft
- $h_2 = 100$ ft
- $K = 100$ ft/d
- $S_y = 0.1$
- $x_L = y_L = 1000$ ft
- $\Delta x = \Delta y = 100$ ft
- $C_1 = 2 \times 10^6$ ft^2/d
- $C_2 = 1 \times 10^6$ ft^2/d



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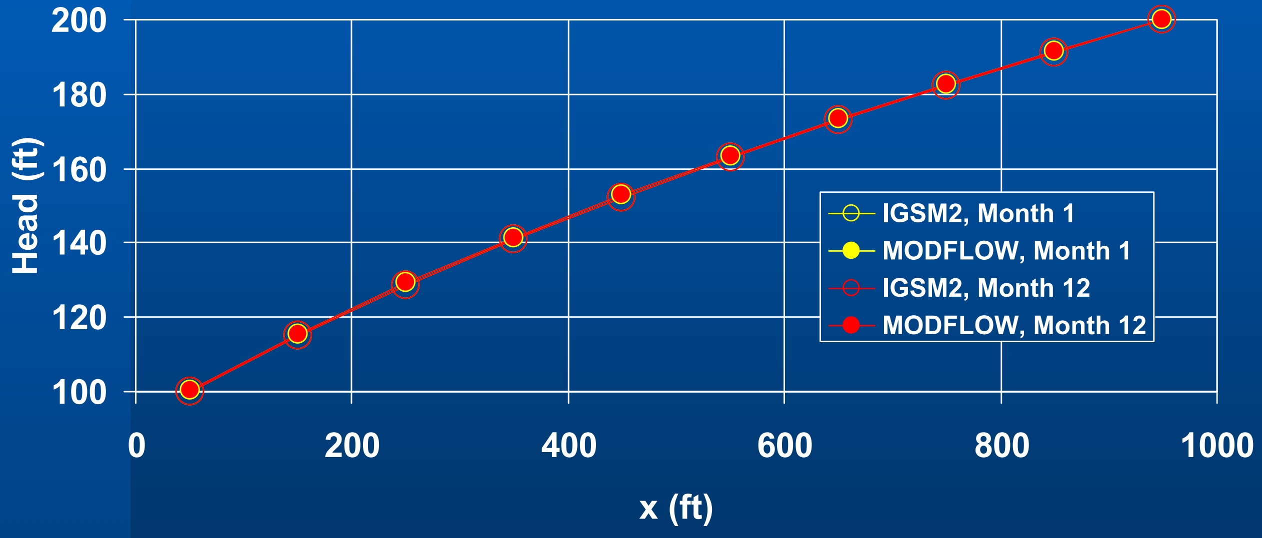
Problem 1c



Comparison of Performance: IGSM2 and MODFLOW (from CWEMF review of IGSM)

Problem 1d

$h_o = h_1 = 200$ ft

$h_2 = 100$ ft

$K = 100$ ft/d

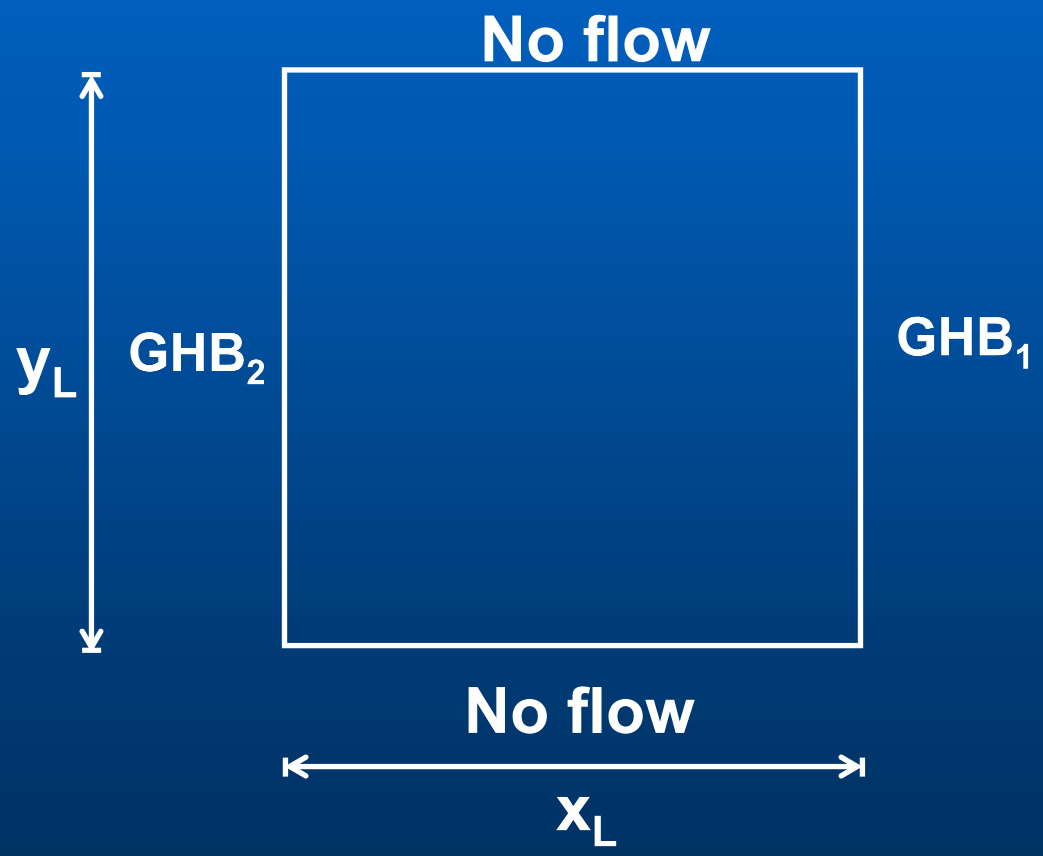
$S_y = 0.1$

$x_L = y_L = 10000$ ft

$\Delta x = \Delta y = 1000$ ft

$C_1 = 2 \times 10^7$ ft^2/d

$C_2 = 1 \times 10^7$ ft^2/d



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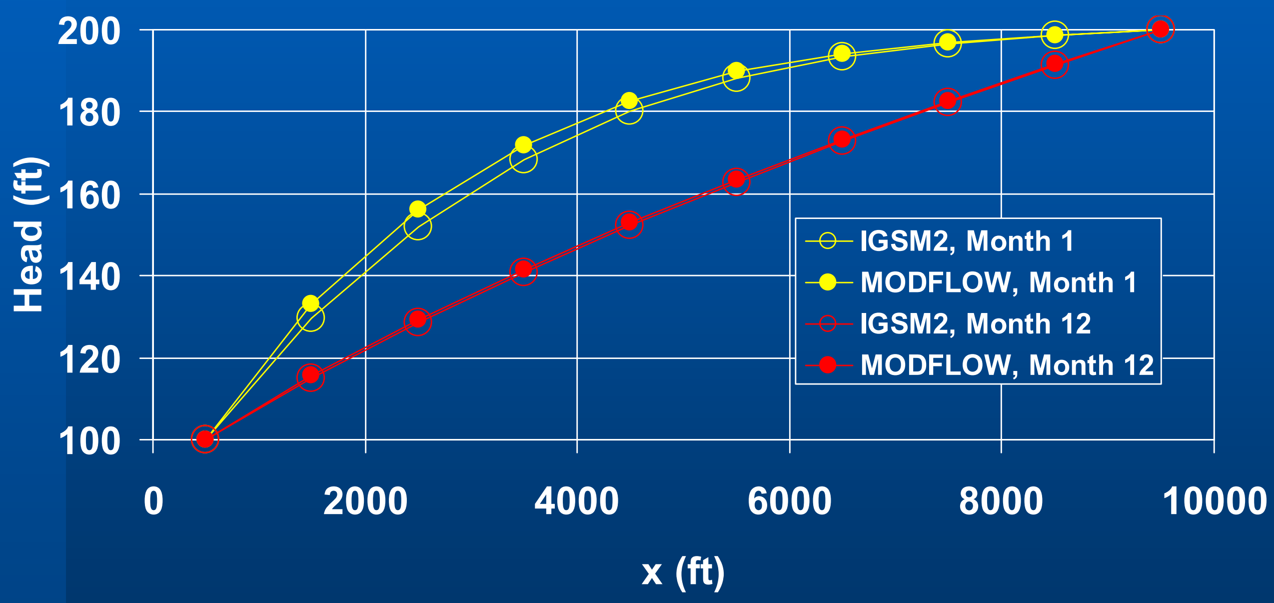
Problem 1d



Comparison of Performance: IGSM2 and MODFLOW (from CWEMF review of IGSM)

Problem 2a

$h_o = h_1 = h_2 = 195$ ft

$z_d = 192$ ft

$B_d = 50$ ft

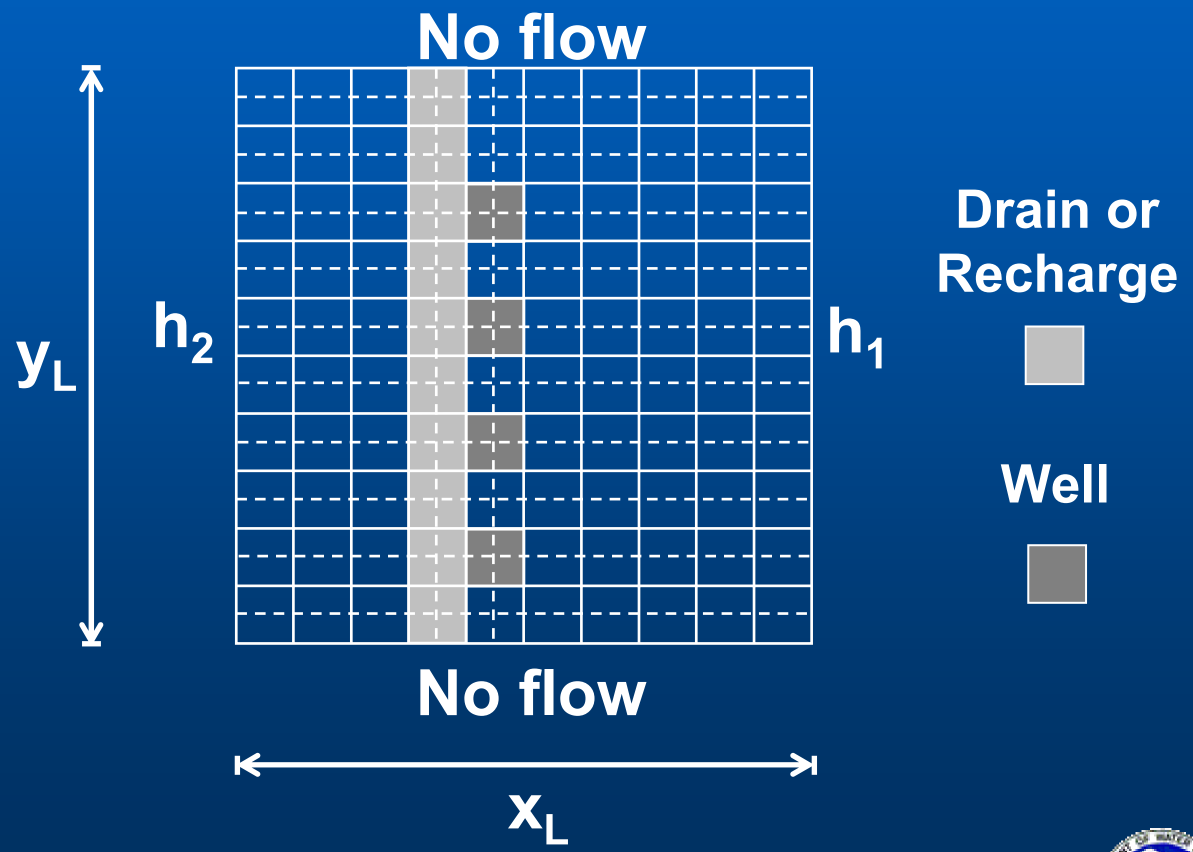
$K = 20$ ft/d

$S_y = 0.1$

$x_L = y_L = 10000$ ft

$\Delta x = \Delta y = 1000$ ft

$C_d = 4 \times 10^5$ ft^2/d



Comparison of Performance: IGSM2 and MODFLOW (from CWEMF review of IGSM)

Problems 2a – 2c

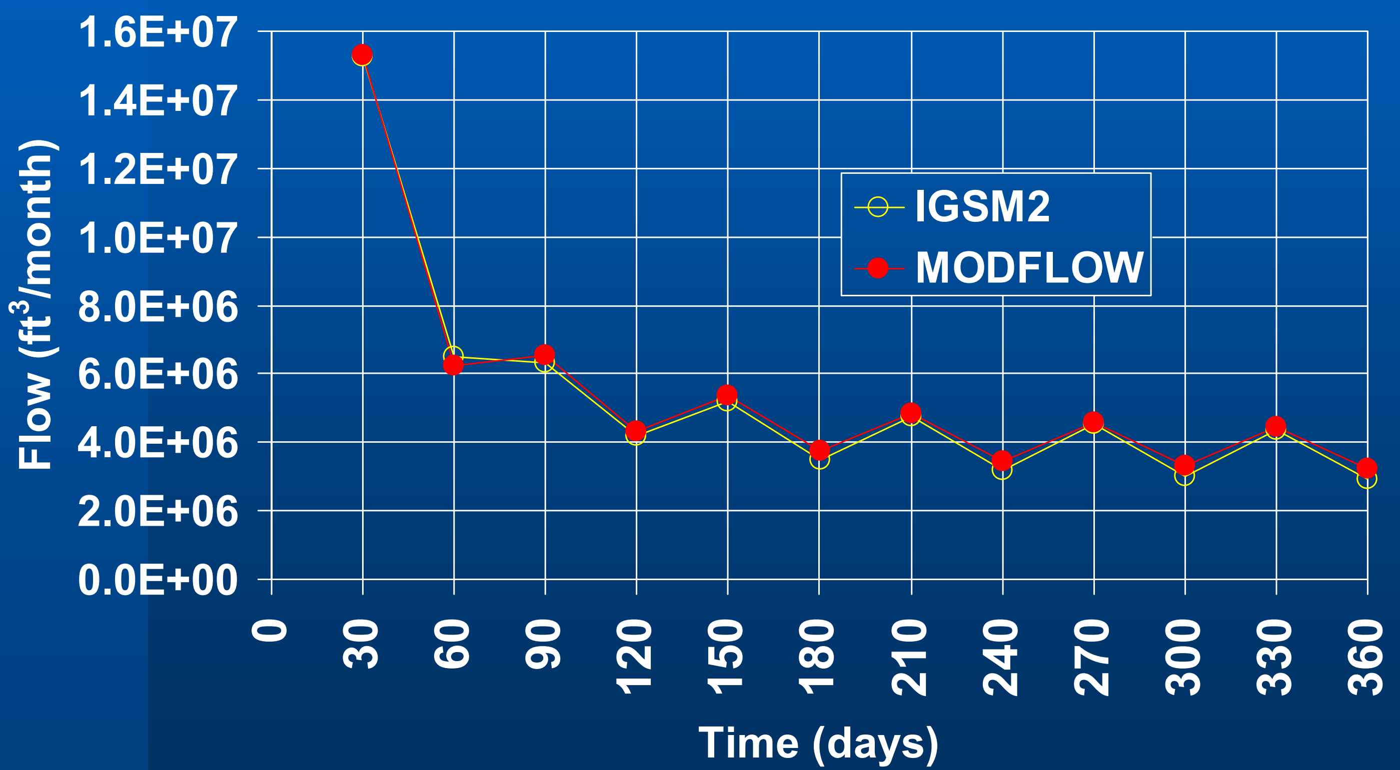
Month	Pumping* (gpm)	Recharge** (ft/day)
1	0	0.02592
2	2452	0.02592
3	0	0.02592
4	2452	0.02592
5	0	0.02592
6	2452	0.02592
7	0	0.02592
8	2452	0.02592
9	0	0.02592
10	2452	0.02592
11	0	0.02592
12	2452	0.02592

* Distributed equally among 4 nodes

** Applied to 10 nodes with tile drains

Comparison of Performance: IGSM2 and MODFLOW (from CWEMF review of IGSM)

Problem 2a



Comparison of Performance: IGSM2 and MODFLOW (from CWEMF review of IGSM)

Problem 2b

$h_o = h_1 = h_2 = 195$ ft

$z_d = 192$ ft

$B_d = 50$ ft

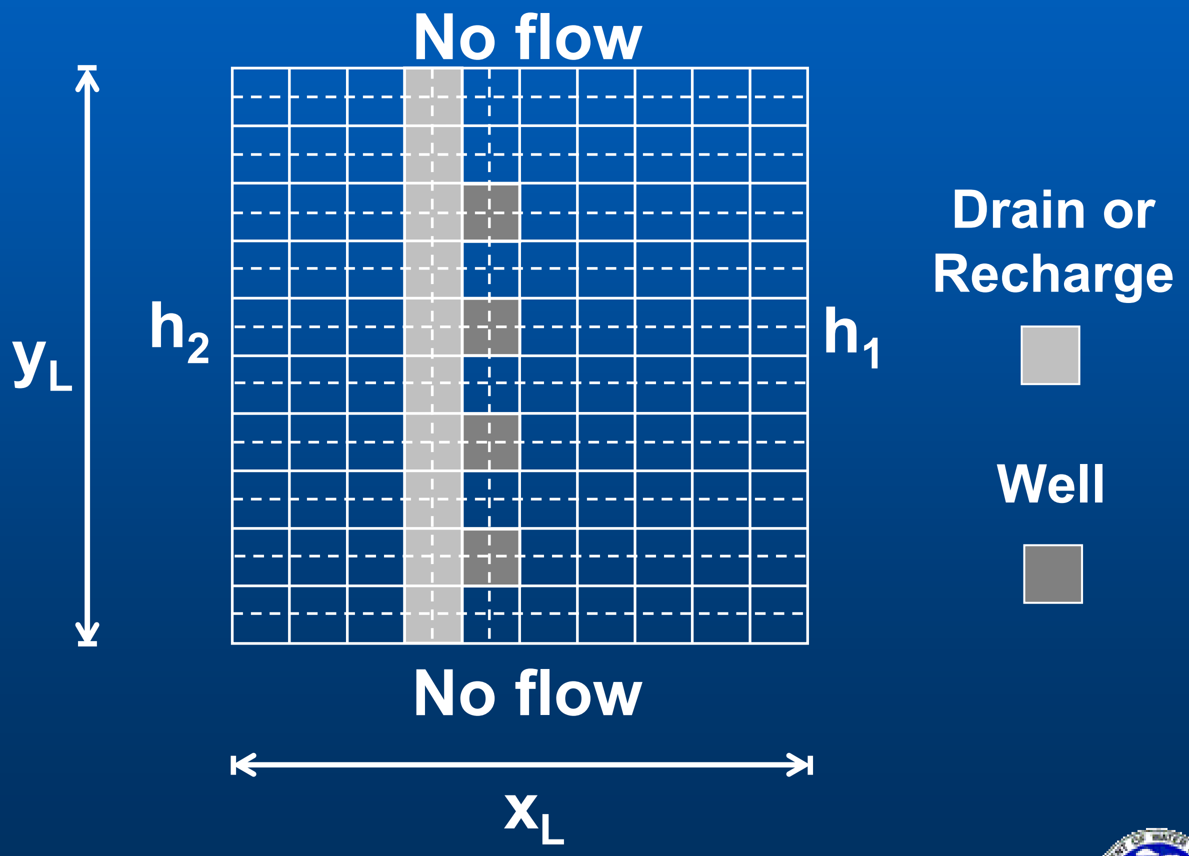
$K = 20$ ft/d

$S_y = 0.1$

$x_L = y_L = 10000$ ft

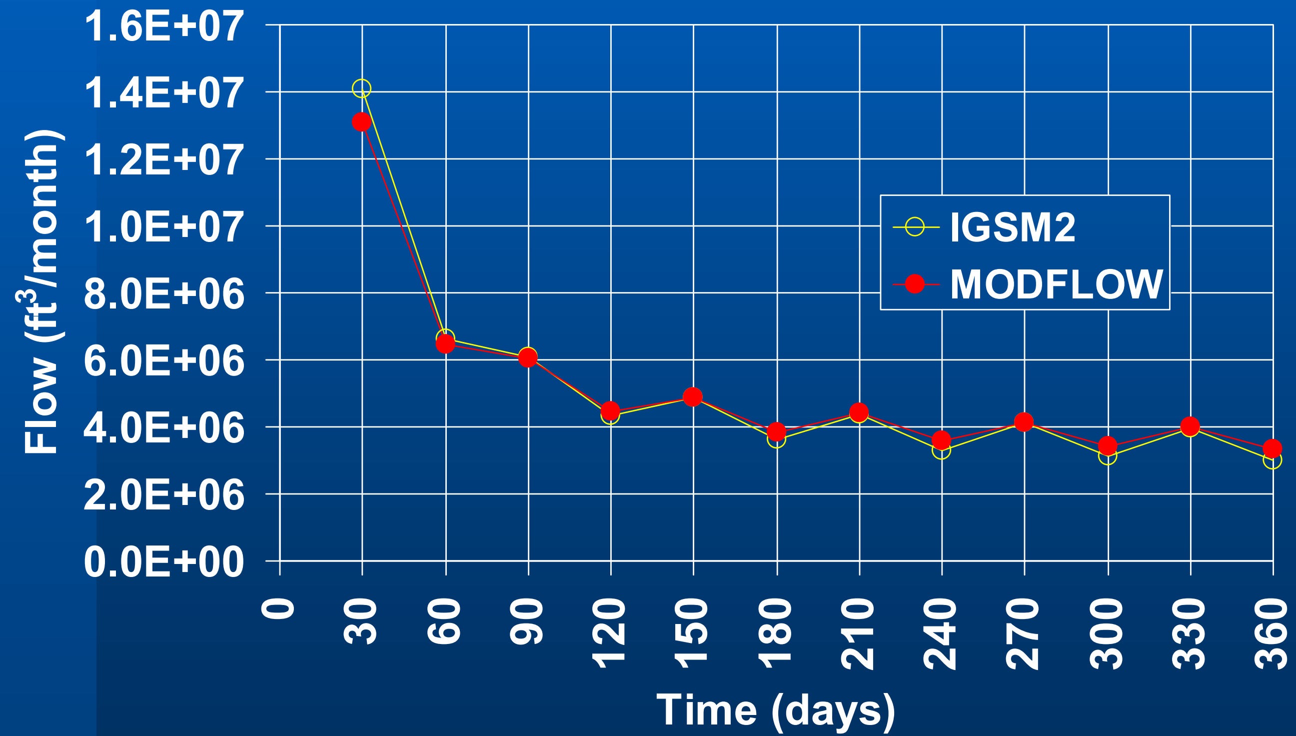
$\Delta x = \Delta y = 1000$ ft

$C_d = 4 \times 10^4$ ft^2/d



Comparison of Performance: IGSM2 and MODFLOW (from CWEMF review of IGSM)

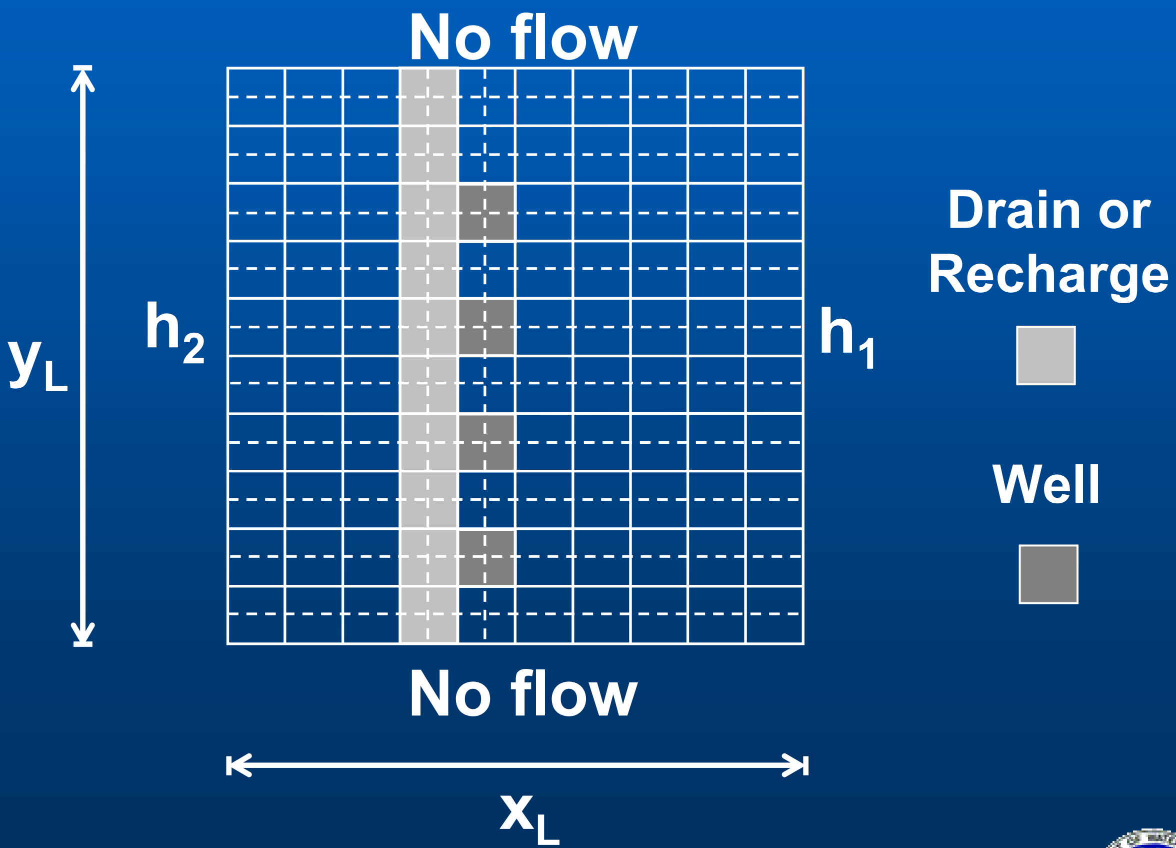
Problem 2b



Comparison of Performance: IGSM2 and MODFLOW (from CWEMF review of IGSM)

Problem 2c

- $h_o = h_1 = h_2 = 195$ ft
- $z_d = 192$ ft
- $B_d = 50$ ft
- $K = 20$ ft/d
- $S_y = 0.1$
- $x_L = y_L = 10000$ ft
- $\Delta x = \Delta y = 1000$ ft
- $C_d = 4 \times 10^3$ ft^2/d



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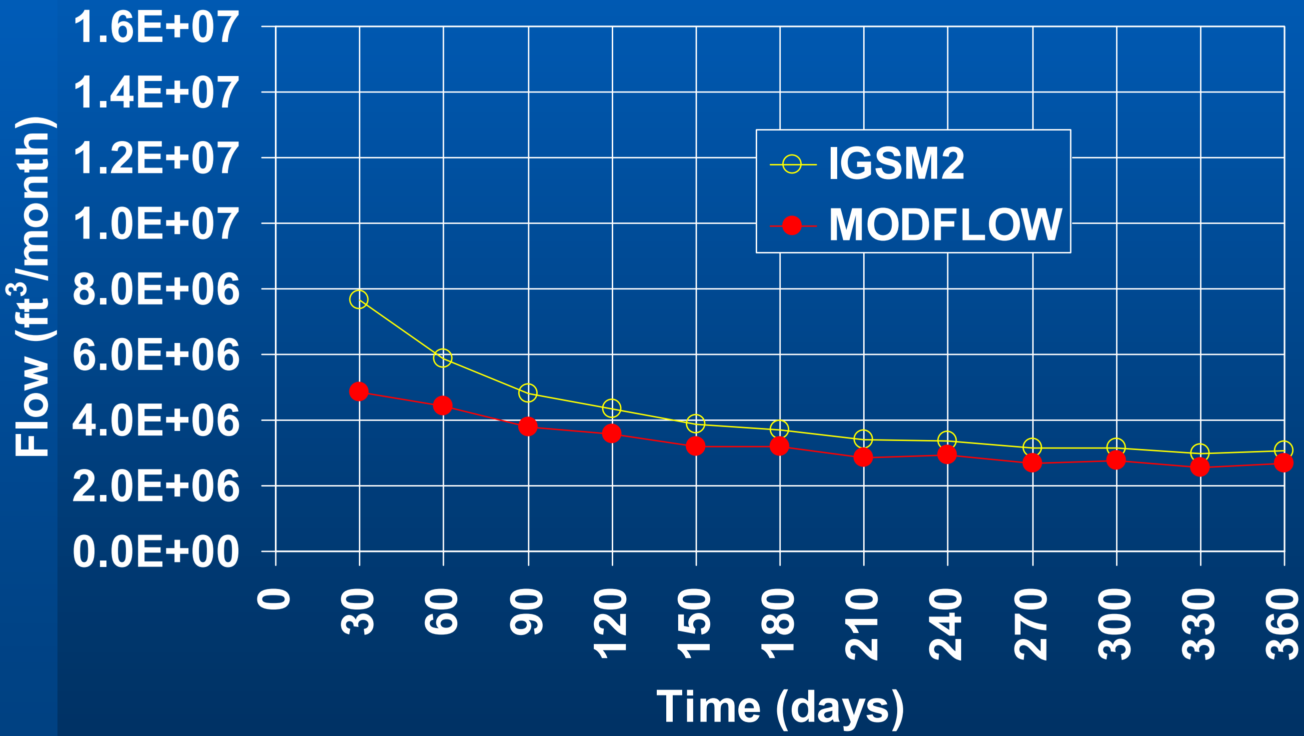
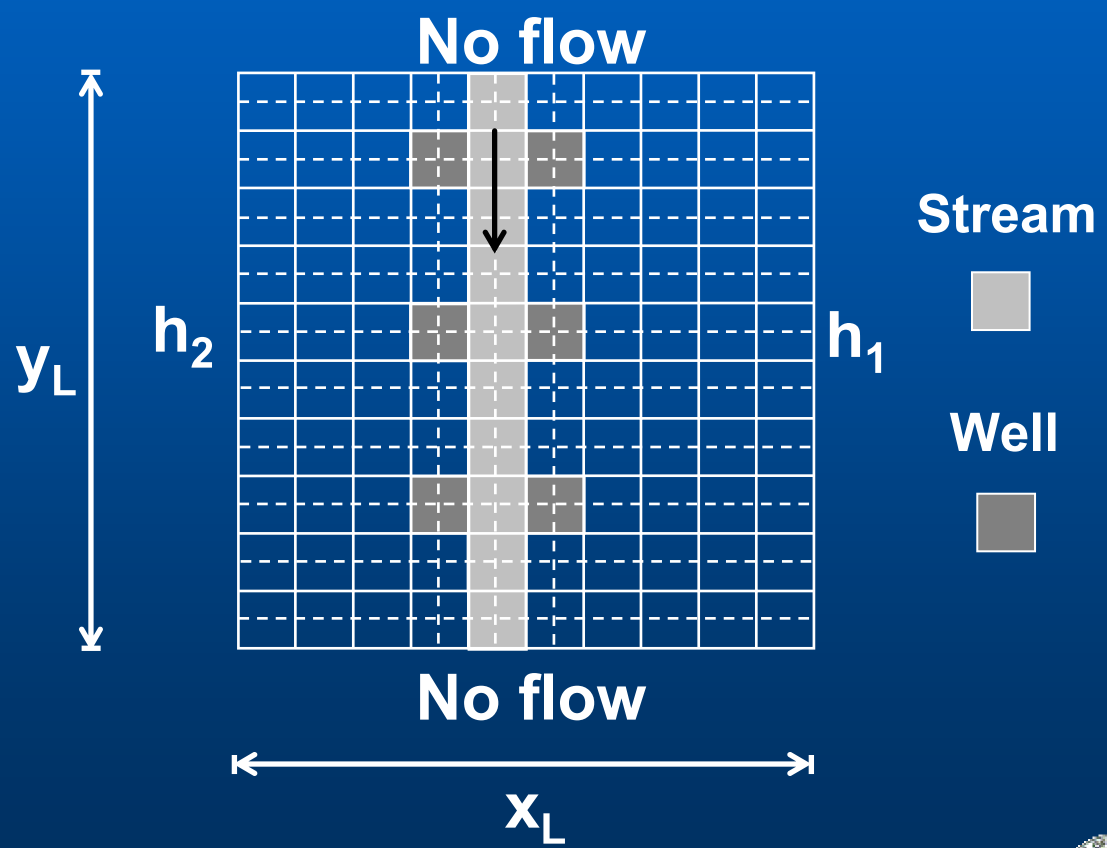
Problem 2c



Comparison of Performance: IGSM2 and MODFLOW (from CWEMF review of IGSM)

Problem 3b
(Scenario 3)

- $h_o = h_1 = h_2 = 200$ ft
- $b_r = 180$ ft
- $K = 100$ ft/d
- $S_y = 0.1$
- $x_L = y_L = 10000$ ft
- $\Delta x = \Delta y = 1000$ ft
- $C_r = 10$ ft^2/d
- Inflow = 100 cfs



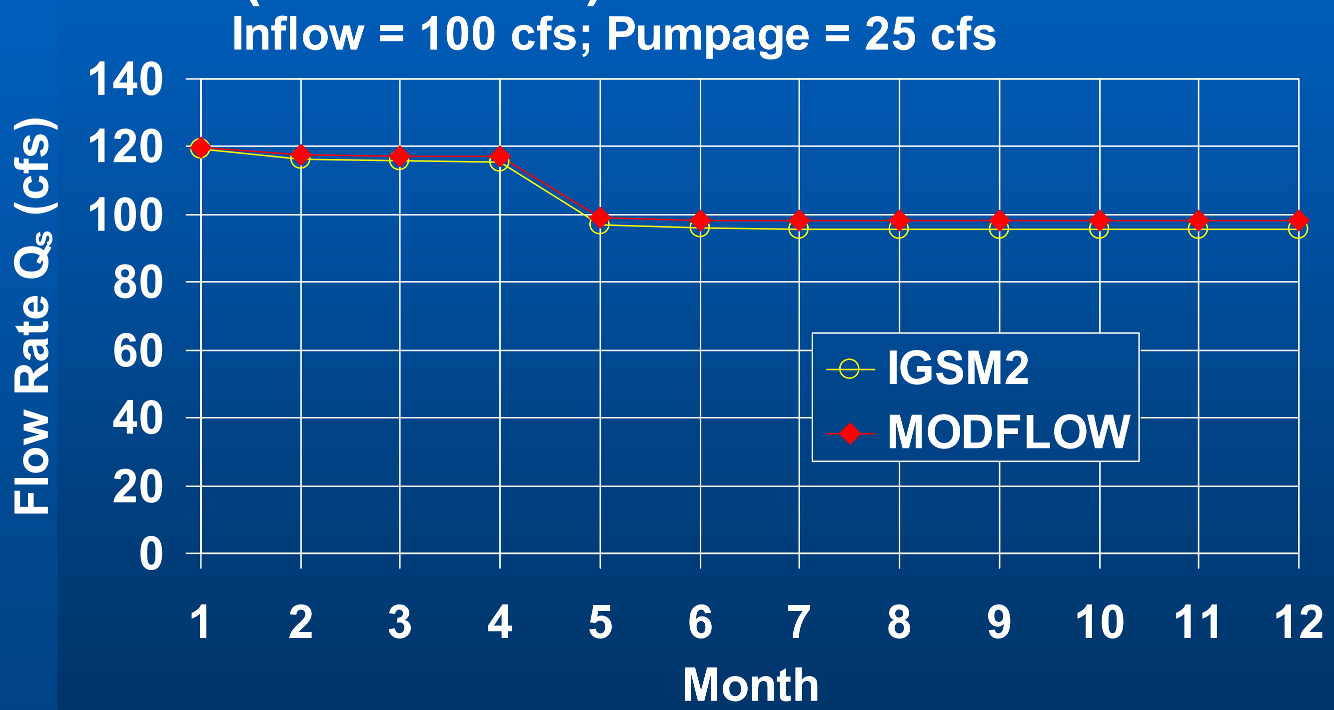
Comparison of Performance: IGSM2 and MODFLOW (from CWEMF review of IGSM)

Problem 3b
(Scenario 3)

Month	Pumping (cfs)	Inflow (cfs)
1	0	100
2	0	100
3	0	100
4	0	100
5	0	100
6	25	100
7	25	100
8	25	100
9	25	100
10	25	100
11	25	100
12	25	100

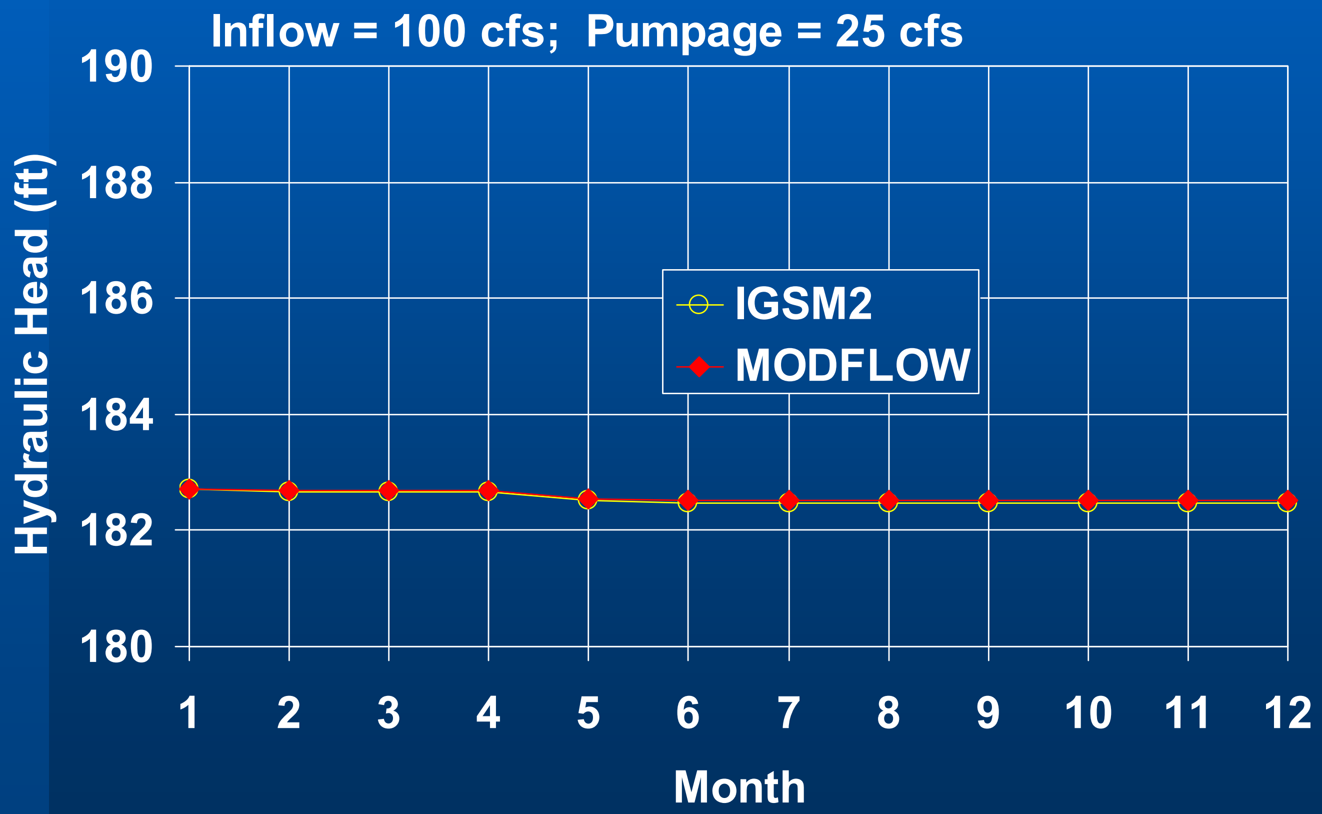
Comparison of Performance: IGSM2 and MODFLOW (from CWEMF review of IGSM)

Problem 3b (Scenario 3)



Comparison of Performance: IGSM2 and MODFLOW (from CWEMF review of IGSM)

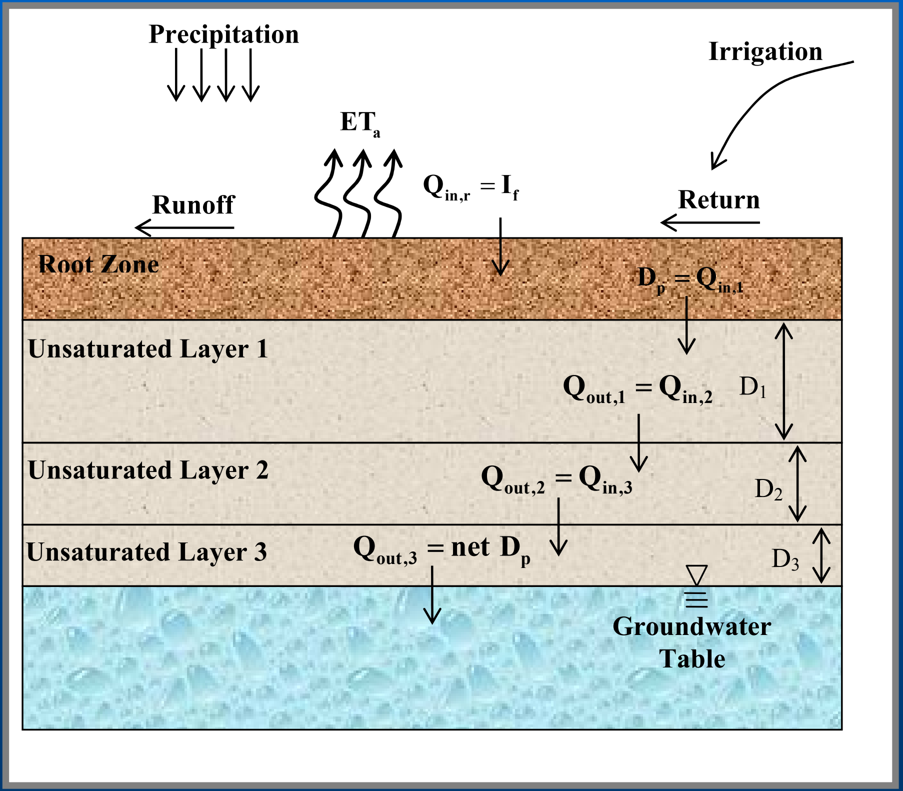
Problem 3b (Scenario 3)



Soil Moisture Routing

- Precipitation and irrigation less direct runoff and return flow is the inflow into root zone
- Deep percolation from root zone is the inflow into unsaturated zone
- Net deep percolation from unsaturated zone is the recharge to groundwater
- Conservation of mass:

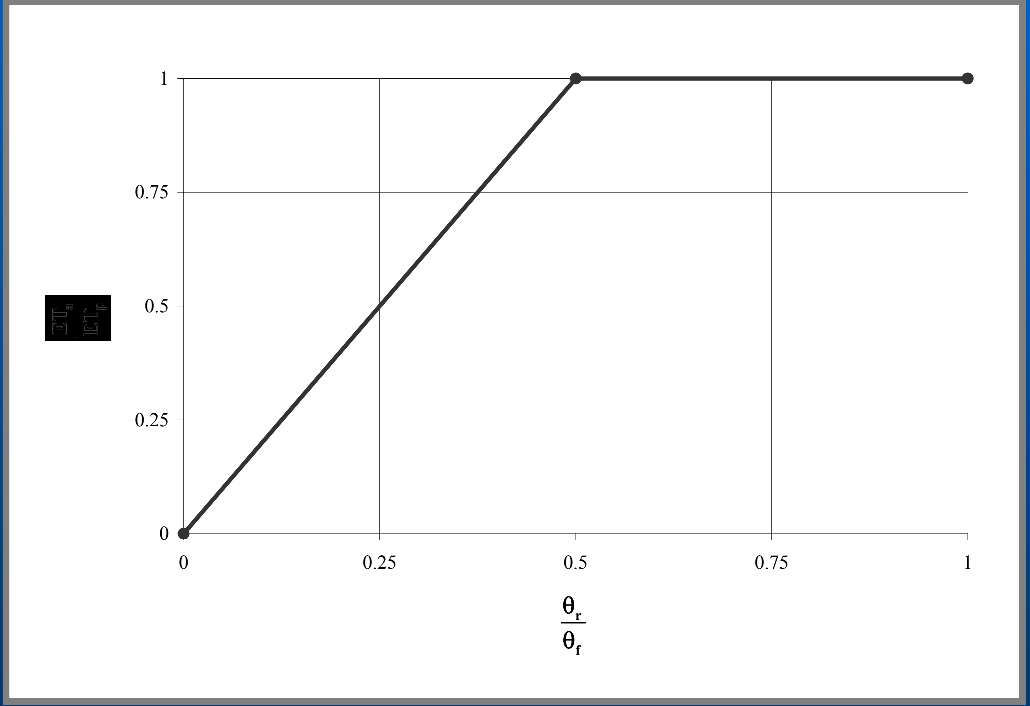
$$D\left(\frac{\theta^{t+1}-\theta^{t}}{\Delta t}\right)=Q_{in}^{t+1}-ET^{t+1}-K_s\left(\frac{\theta^{t+1}}{\eta_T}\right)^4$$



Evapotranspiration

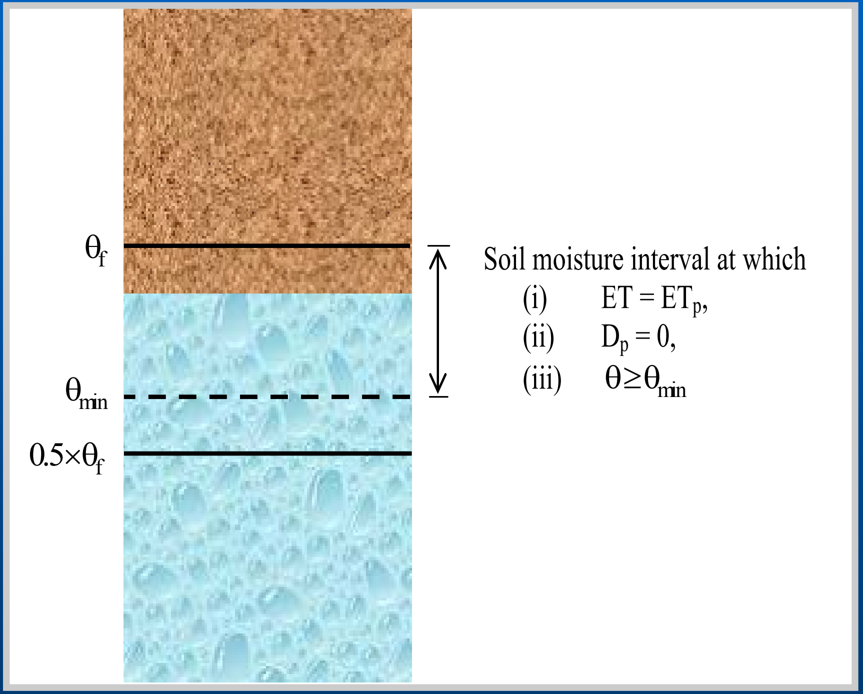
- **Time dependent ET is computed as a function of soil moisture in the root zone, field capacity and potential ET**
- **(FAO, 1998):**

$$ET_a = \begin{cases} 2ET_p\dfrac{\theta_r}{\theta_f} & \text{if } 0 < \dfrac{\theta_r}{\theta_f} \le 0.5 \\ ET_p & \text{if } 0.5 < \dfrac{\theta_r}{\theta_f} \end{cases}$$



Agricultural Demand

- The required amount of applied water in order to maintain optimum agricultural conditions
- At optimum agricultural conditions
- (1) ET rates are at their potential levels for proper crop growth
- (2) soil moisture loss as deep percolation is minimized
- (3) minimum soil moisture requirement for each crop is met at all times



Other Important Features of IGSM2

- Functionality of variable time step is included in the code; internal computations are currently done on a daily time step
- Complete theoretical documentation and user's manual
- Proper modeling of lake-groundwater interaction similar to the modeling of stream-groundwater interaction
- Nonlinear computation of groundwater pumping in the event of drying aquifer
- Improved computation and appearance of budget tables
- Dynamic dimensioning of the program arrays

Near-Future Improvements for IGSM2

- Automated adjustment of surface water diversions and groundwater pumping to meet the urban and agricultural demand
- Implementation of numerical techniques to present proper groundwater budgeting for subsections of the modeled area (equivalent to Zonebudget in MODFLOW)
- Ability to run IGSM2 for adjacent model domains sequentially
- Additional documentation of the computer code (inclusion of list of variables, their meanings and inclusion of comment lines)

Future Improvements for IGSM2

- Inclusion of reservoir operations and water rights simulation package
- Full flexibility of variable time step
- Soil moisture routing over each element
- Capability of recognizing standard database file inputs (e.g. HEC-DSS)
- Development of a GUI
- Enhancing CALSIM II (coupling with IGSM2)

<u>**Ultimate Goal:**</u>

Continue enhancing IGSM2 according to the feedback received from the user's group